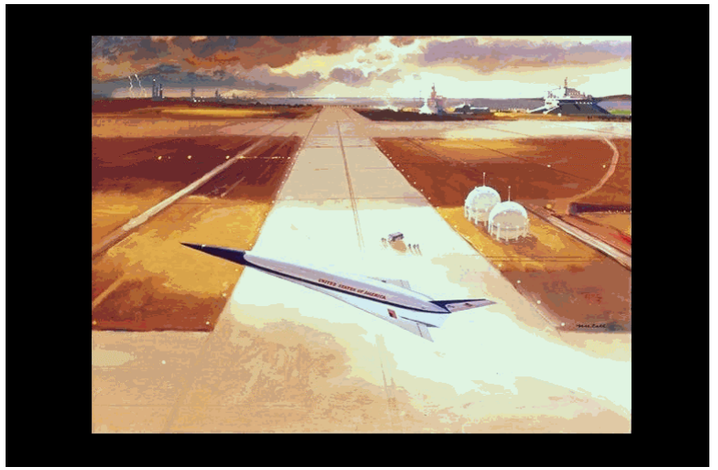
		Structures/Mechanical	*Payload*	*Ground Supportability*
Integrate		✓Cross sections of tankage/load bearing structure to reduce closed compartments & aeroshells (1, p4) ✓Tankage and TPS to eliminate aeroshells & closed compartments (2, p30-31, p39-40) ✓Tanks for common fluids (LOX, LH2, GHe…) (2, p37) ✓Tanks for multiple systems (MPS, OMS, RCS, power, thermal management) (1, p3) (2,p34-35) (3)	✓Payload containment with the vehicle structure & outer mold line function (5)	✓Flight to ground interfaces (1, p9) ✓Components of launch umbilical (electrical connectors, fluid disconnects, structure,…) (5) ✓Ground test, launch, and flight control software (5) ✓Processing facility and control room infrastructure (4, Gen15) ✓Loading umbilicals (fill, drain, power, comm.,…) and tank vents (GOX, GH2) into same umbilicals at base (5).
Eliminate		✓Toxic waterproofing for TPS (2, p22-24) (5) ✓Need for waterproofing TPS (2,p22-24) (5) ✓Complex heat shielding (5) ✓Hazardous pyrotechnic/ordnance devices (5) ✓Closed structural compartments (without compromising safety and maintainability) near tanks, around MPS manifold, and near areas containing systems which are prone to outgassing or leakage. (2, p30-31, p39-40) (3) (5) ✓Unnecessary penetrations in pressurized compartments (4,TC1) ✓Mechanical joints (3)	✓Access/entry for removal of integrated cargo element (5) ✓Dependence of payload support on launcher (5) ✓Fluid interfaces between payload and launcher (5) ✓Electrical interfaces (power and communication) between payload and launcher (5) ✓Monitoring of payload during cruise phase (5)	✓Toxic fluids for servicing, manufacturing, assembling, and cleaning (1, p4,8) (2, p22-24, 58-59,68) ✓High parts count (1, p6) (2, p63-64) ✓Large support staff (1, p5) ✓Hands-on, intrusive ground support activity (1, p10) (2, p52-54) (5) ✓Hard-line data links from vehicle to launch pad and LCC (5) ✓Need for complex sound suppression systems (5) ✓Swing arms / arm type vents at pad and ordnance / events at launch (3, p30,37,39) (5) ✓Vehicle cannibalization (5)
Design In	**Maintainability**	✓Accessibility without requiring special GSE, access kits, or non-affected line replaceable unit removal (1, p6) ✓Fluid/gas connections that do not require process control (i.e. leak-checking) *after* assembly (1, p11) (2, p44-47) ✓Robustness and/or Built-in-Test and verification devices to verify/assure structural safety (2, p27-28) (5) ✓Common fasteners (5) ✓Robustness and/or TPS quick removal and replacement (2,p53) (4, p48)	✓Standard payload interfaces (5) ✓Standard communication/data protocols (5) ✓Fluid/gas connections that do not require process control (i.e. leak-checking) *after* assembly (1, p11) (2, p44-47) ✓Built-in-tests to verify payload health (5) ✓Minimum attachment interfaces (5) ✓Minimum number of different fluids (5) ✓Minimum wire count (5)	✓Minimum test hardware interfaces, utilize built-in-test to verify launch readiness (5)
	Reliability	✓Corrosion resistant materials (5) ✓TPS that does not require routine inspection (2,p53) (5) ✓Minimum parts count (2,p63-64) (5) ✓Minimum susceptibility to critical fatigue (5)	✓Commercial off-the-shelf products produced in high quantities (bus, electronics, power, actuators,…) (1, p5)	✓Commercial off-the-shelf (COTS) products produced in high quantities (quick disconnects, valves, software, controllers, PLCs, sensors,…) (2,p41-43) (5)
	Margin	✓Margins in structures that eliminate intrusive inspections for corrosion, primer, defects (5) ✓Robust, weather tolerant TPS (2, p22-24) ✓Robust, weather tolerant windows (5) (2,p13-16,p25-26)	✓Performance to provide for payload flexibility and growth (1, p12) (2, p58-59)	✓Ground systems robust to failures through redundancies for critical systems (5) ✓Ground/flight sys. with requirements capable of being satisfied by wide array of COTS products (5)
Automate		✓Leak *location* / diagnostics (not just detection) (3) ✓Landing gear ground (test) operations (4, GNC8) ✓Add / build in integrated vehicle health management (IVHM) systems (4, GNC 13) ✓Brake/anti-skid test and checkout (4, GNC9)	✓Checkout of payload interface to vehicle (4, p33) ✓Cruise operations (5) ✓Scientific data collection and distribution process (5)	✓Maintenance tracking and scheduling to subsystem level (5) ✓Failure reporting system (5) ✓Launch processing operations and mission planning (5) ✓Flight crew active control functions (5) ✓Checkout and troubleshooting of flight to ground interfaces (fluid, power, communication, and structural) (5) ✓Ground System Checkout & troubleshooting (5) ✓Loading/servicing of launch vehicle (5)

REFERENCES

1. Architectural Assessment Tool, Space Propulsion Synergy Team (SPST), Oct., 1997.
2. A Guide for the Design of Highly Reusable Space Transportation, SPST, Aug., 1997.
3. Operationally Efficient Propulsion System Study (OEPSS), Rocketdyne Division, Rockwell International, Aug., 1993.
4. Shuttle Avionics Testing Constraints and Considerations, Carey McCleskey, NASA Kennedy Space Center, June, 1995.
5. For further information, contact Edgar Zapata, 407-861-3955, NASA Kennedy Space Center.



DESIGN GUIDELINES

A. Reduce the overall number of different fluids; do not use toxic fluids.
B. Integrate propulsion system components.
C. Use reliable, commercial off-the-shelf products that are produced in high quantities.
D. Automate checkouts of systems and turnaround facilities.
E. Design for accessibility without requiring special GSE, access kits, or non-affected line-replaceable unit removal.
F. Minimize interfaces between flight and ground.

Prepared by
Rebecca Cutri-Kohart

		Propulsion	***Avionics*** *(GNC, communication, computing, power management)*
Integrate		✓MPS and OMS engine function (1, p3) (2, p34-35,72) (3) (5) ✓OMS and RCS tanks (1, p3) ✓Oxidizer for MPS, OMS, RCS, power, thermal management (1, p8) (2, p22,34,58) ✓Fuel types, use identical fuel grades for common fluid systems (2, p58) (5) ✓Interfaces (connectors/quick disconnects) between flight and ground (3) (5) ✓N-turbopumps with X-engines to minimize the count of turbopumps (shared turbopumps) (2, p72) (3) (5) ✓Engine controllers (share with engines and/or avionics) (3)	✓Hardware (avionics controls with engine controller, vehicle health system, or ground equipment) (3) ✓Electrical connectors between flight and ground (5) ✓Navigation equipment and traditional direct air-stream sensing (4, GNC16)
Eliminate		✓Toxic propellants (1, p8) (2, p22-24,68) (5) ✓Confined spaces with hazardous fluid potential (2, p30-31,68) (3) (5) ✓GHe/GN2 purges for confined spaces (1, p 6) (2, p39-40) ✓Confined spaces requiring environmental conditioning (1, p 6) (2, p 39-40) ✓Fluid joints and electrical conductor counts (2, p58-59) ✓Large number of gases for flight operations (1, p9) ✓Active engine events during flight (staging, mixture ratio changing, throttling, mode changes) (1, p4) (3) ✓Turbopump inner seal purge (2, p44-45) (3) ✓LOX pump seal leakage (3) ✓Helium gas usage, pneumatic valve actuators (5) (3) ✓Helium gas usage for pressurization (3) ✓Leak potentials (minimize) (3) ✓Distributive hydraulic systems (1, p8) (2, p22-24,68) (5)	✓Toxic cooling fluids, such as freons, ammonia (1,p8) (2, p22-24,58-59,68) ✓Need for multiple telemetry formats (downlink and downlist) (4, Gen2) ✓Active cooling for avionics boxes (4, Gen3) ✓Checkout requirements due to connector demates/remates (4, Gen4) ✓Possibility of engine collision (4, GNC2) ✓Procedural restrictions on actuator movement (4, GNC5) ✓Special cleaning/access requirements (such as for the star tracker lens and light shade inspections) (4,GNC14) ✓Materials that outgas (4,GNC15)
Design In	**Maintainability**	✓Built-in-test, troubleshooting, and diagnostics (1, p10) (2, p27-28) (3) (5) ✓Accessibility without requiring special GSE, access kits, or non-effected line replaceable unit removal (1, p 6) (5) ✓Minimum number of different propellants (5) ✓Electro-mechanical actuators (EMA) or electro-hydrostatic (EHA) actuators for gimbaling/TVC (5) (3)	✓Minimum fluid interfaces (2, p44-47) ✓Minimum wire count (4, Gen4) ✓Minimum connector interfaces (2, p44-47) ✓Minimum attachment interfaces (5) ✓Minimum the number of checkouts required (2, p67) ✓Ergonomic access to line replaceable units (LRU) - accessibility without requiring special GSE, access kits or non-effected LRU removal (4, Gen9) ✓ Built-in-Tests (BIT) to monitor vehicle health and troubleshoot (5) ✓ Installation and fastening devices (4, Gen10)
	Reliability	✓Commercial off-the-shelf products produced in high quantities (such as electronics, controls, valves, sensors,…) (1, p5) (3) ✓Expert systems to control complex loading and launch operations (5)	✓Commercial off-the-shelf products produced in high quantities (such as software, processors, displays,…) (1, p5)
	Margin	✓Operate engines farther from the design edge - less than 100% of design/test thrust rating (2, p25-26)	✓In temperature and other operating environment restrictions (4, GNC6) ✓Hardware immunity to contamination and physical damage (4, GNC15)
Automate		✓Turnaround functions, such as leak, valve, electrical, hydraulic, and engine systems checkouts (2, p49-51) ✓Interface connection/disconnection for fluid and electrical checkouts (5)	✓Functions on-board vehicle instead of or in addition to ground (4, Gen6) ✓Redundant power verification during power-up or system activation (4, Gen13) ✓Checkout of redundant systems (4, Gen8) ✓Checkout functions for motorized systems (5)

Space Transportation Systems

Operability

Quick Reference